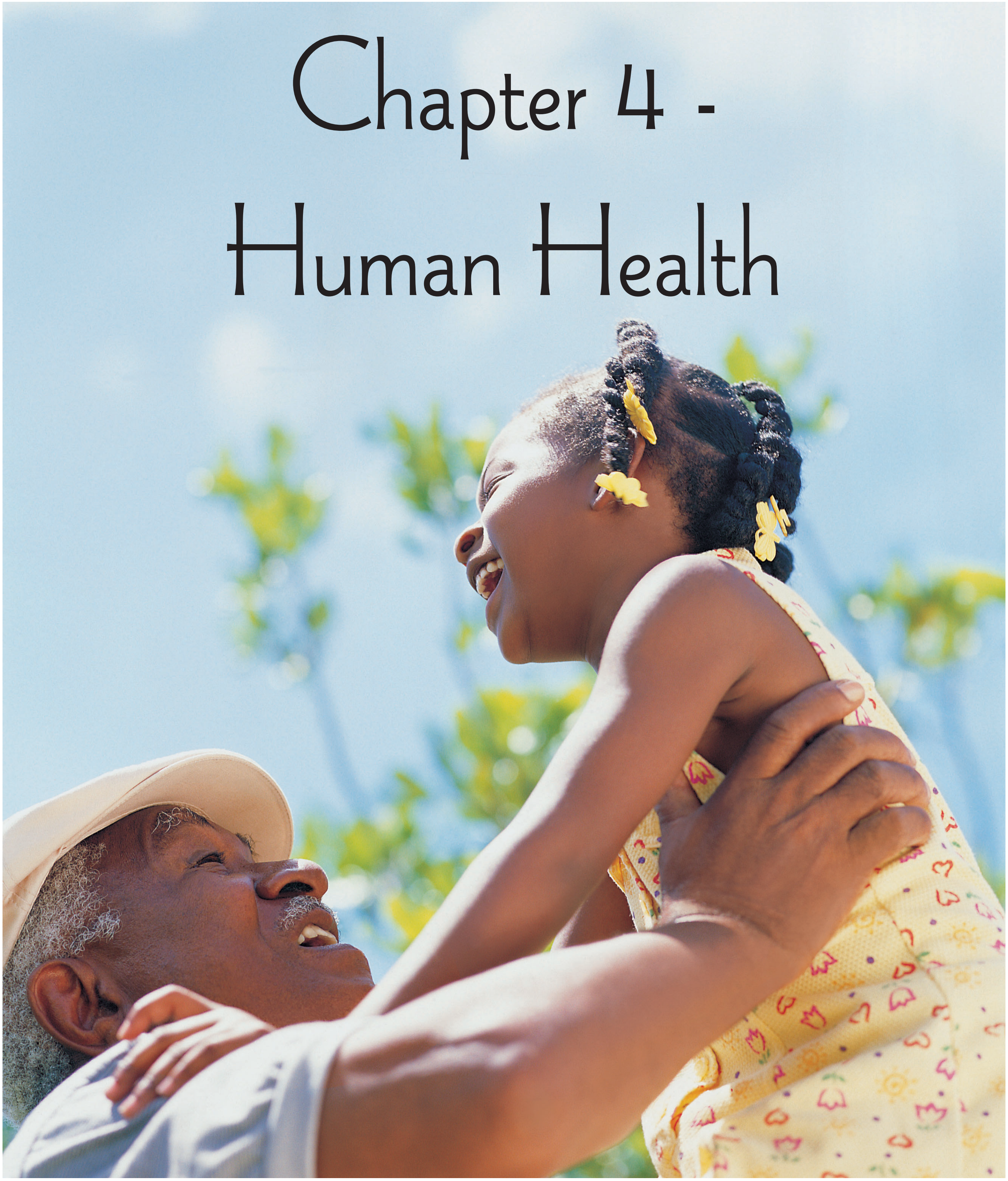
Chapter 4 - Human Health



Introduction

Protecting the health of Americans from environmental pollutants has always been a key goal of EPA policies and programs. EPA has taken a number of actions to fulfill this goal, including establishing standards for pollutants in the environment, requiring sources to limit their pollution, and educating members of the public about actions they can take to protect their health. The indicators presented in Chapters 1 through 3 provide a measure of the progress that has been made in reducing environmental pollution in air, water, and land.

EPA is moving, where possible, to supplement the measures described in the earlier chapters with outcome indicators that could provide a clearer understanding of how environmental factors contribute to public health outcomes such as disease trends. Information on whether particular death and disease rates are going up or down, along with information on the various environmental and other factors that influence these trends, would strengthen environmental decision-making and evaluation. For example, this type of information could help EPA evaluate not only whether air quality has improved, but also whether rates of respiratory problems associated with air pollution have improved, and if not, why.

Developing these types of outcome measures is challenging for many reasons:

- Although numerous health problems have suspected links to environmental pollution, many factors in addition to the environment influence whether a person who comes in contact with a pollutant will ever show symptoms of exposure or develop disease. Those factors include the quantity and type of pollutant, the number of contacts with it, and a person's age, health, genetic make-up, and lifestyle.

- A pollutant's impact may range along a continuum from no effect to mild symptoms to serious acute or chronic impacts. Different people have different vulnerabilities, so some may experience effects at ambient pollutant levels while others may not.

- Researchers have had success elucidating the linkage between individual pollutants and health. In reality, however, people are more typically exposed to a number of pollutants. How pollutants interact, and how exposure to multiple pollutants affects health, is not well understood at present.

EPA is working to lay the foundation for developing effective measures for tracking progress in protecting human health from environmental pollution. These include measures of outcomes, such as diseases, as well as biomonitoring measures that can tell us, for example, how much of a certain pollutant has penetrated into and resides within our blood and tissue.

This chapter describes key elements that begin to establish a basis for developing and using environmental public health indicators:

- The chapter begins with an overview of the major trends and indicators for health and disease in the U.S.

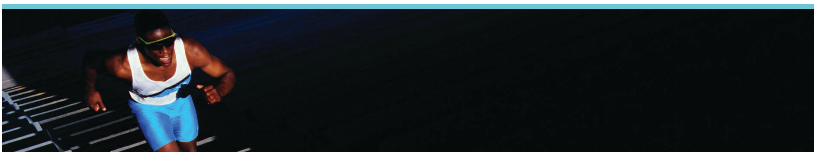
- Next, the chapter examines the role of the environment in disease. Understanding the linkage between exposure and health effects is a critical foundation for the development and use of environmental public health indicators.

Chapter 4: Human Health

- Health Status of the United States
- Environmental Pollution and Disease
- Measuring Exposure to Environmental Pollution
- Challenges in Developing Human Health Indicators

- Examples are presented that demonstrate this linkage and illustrate how environmental health indicators can strengthen environmental management decision-making and evaluation.
- Then, the chapter describes the approaches to measuring exposure to environmental pollution. A number of these approaches may provide the basis for environmental public health indicators in the future.
- Finally, the chapter concludes with a section on the scientific and data-gathering challenges that lie ahead in developing and using environmental public health indicators.

Changes in the health of a nation's people, both improvements and declines, can take years to detect, and EPA cannot develop this national overview alone. For example, nearly all of the health and exposure information currently available is collected by other federal and state agencies, such as the Centers for Disease Control and Prevention (CDC). Development and use of environmental public health indicators will require continued effective coordination and collaboration among federal and state agencies.



Health Status of the United States

There are several ways to assess the health of a specific group of people or an entire country's population that are used consistently across the world as indicators of health status. They include how long people can expect to live (life expectancy), how many infants die before their first birthday (infant mortality), the major causes of death, and the amount of illness in a national population. Among the most common measurements is the number of deaths caused by disease. The national death rate for a disease—especially if the numbers of early deaths (deaths before the average life expectancy) are high—can be a warning of health problems. This section presents an overview of health and major disease trends in the U.S. Some important diseases are presented that have a major impact on the health of Americans. It is important to note that environmental factors may not play a role in all diseases or causes of death presented in this section.

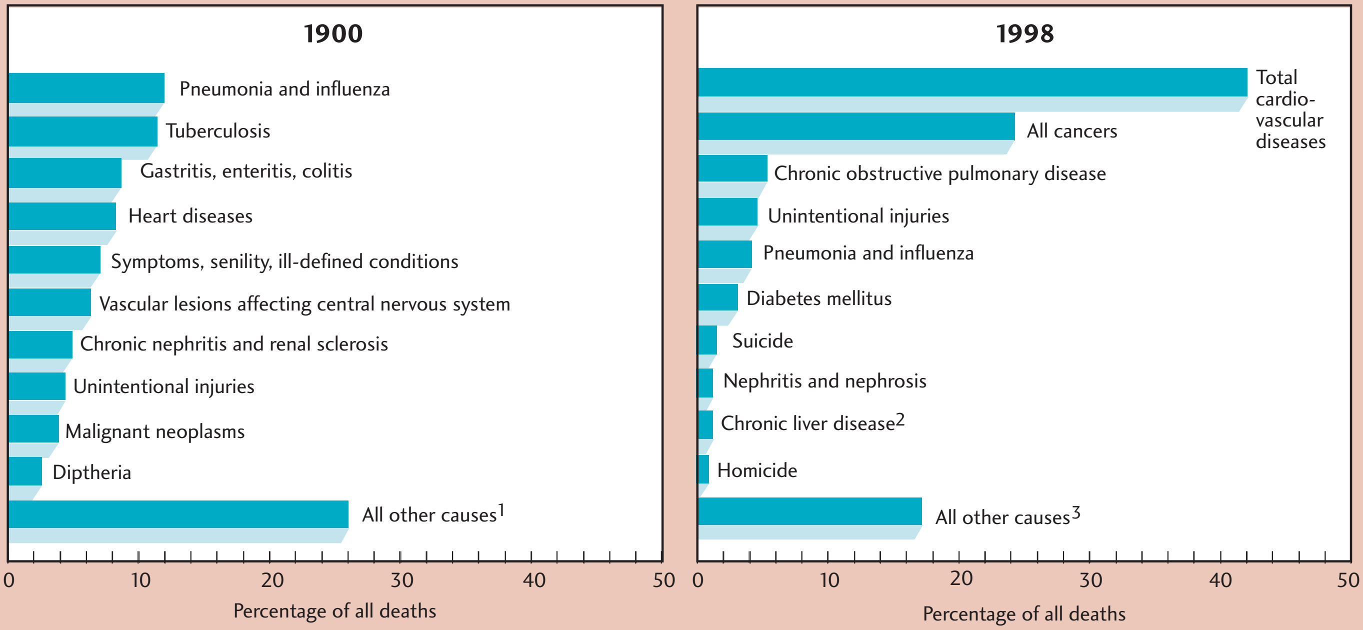
What are the trends and indicators for health and disease in the United States?

The overall health status of the U.S. today is generally good and improving. Over the past century, the nation has basically conquered many infectious diseases that once sickened or killed thousands of people: childhood diseases such as measles and mumps, and waterborne ailments such as typhoid and cholera. Significant progress in improving sanitation and drinking water means that Americans are now relatively safe from the diarrheal diseases that imperil much of the world. Accidents are now the leading threat to children in the U.S., and most adults die from chronic illnesses rather than from infectious diseases (Exhibit 4-1). At the turn of the century, many people died from infectious diseases such as tuberculosis and influenza. Today more than 60 percent of all U.S. deaths are attrib-

Health Status of the United States: Selected Indicators

Life expectancy
Cancer mortality
Cancer incidence
Cardiovascular disease mortality
Cardiovascular disease prevalence
Chronic obstructive pulmonary disease mortality
Asthma mortality
Asthma prevalence
Cholera prevalence
Cryptosporidiosis prevalence
E. coli O157:H7 prevalence
Hepatitis A prevalence
Salmonellosis prevalence
Typhoid fever prevalence
Shigellosis prevalence

Exhibit 4-1: Causes of death, United States, 1900 and 1998



[1] Other casues may include typhoid fever, measles, homicide, suicide, syphilis, and diabetes.
[2] Includes cirrhosis.
[3] Other causes may include motor vehicle accidents, AIDS/HIV, septicemia, Alzheimer's disease, and Parkinson's disease.

Source: CDC, National Center for Chronic Disease Prevention and Health Promotion. *Unrealized Prevention Opportunities: Reducing the Health and Economic Burden of Chronic Disease.* November 2000. Data for 1990 from U. S. Bureau of the Census; data for 1998 from National Center for Health Statistics.

uted to cardiovascular diseases—those involving the heart and blood vessels—and cancer.[1]

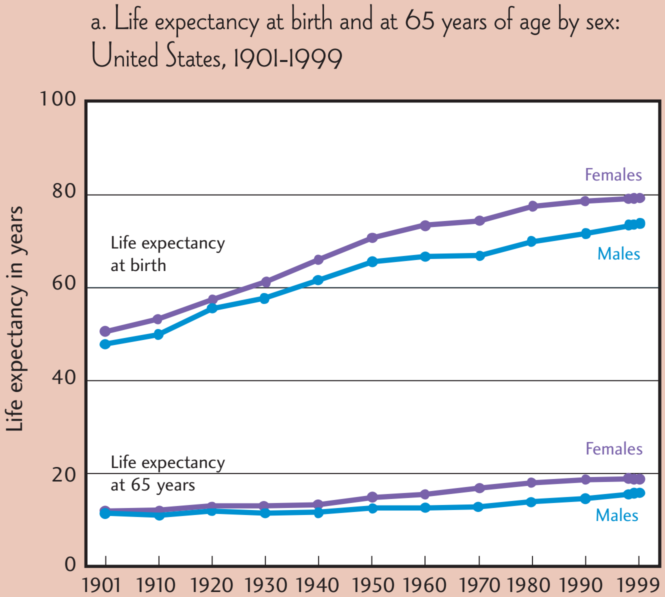
Infant mortality (death) and life expectancy are two key indicators of any nation's overall health (Exhibit 4-2). Infant mortality has dropped to the lowest level ever recorded in the U.S.,[2] but U.S. rates are still higher than those of other developed countries. In 1998, the U.S. ranked 28th out of 38 countries with available statistics for infant mortality.[3]

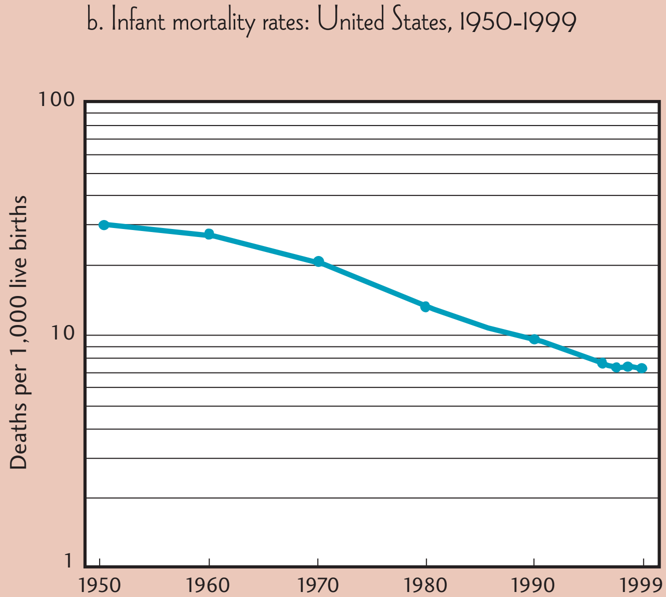
American life expectancy continues to improve. In the last century, life expectancy at birth increased from 51 to 79.4 years for women and from 48 to 73.9 years for men.[4] However, Americans still have a somewhat lower life expectancy than those of other developed countries.[5] In 1997, the U.S. ranked 19th for both males and females in life expectancy, compared with 30 other countries or geographic areas of at least 1 million people. (The U.S. numbers are within 2 years of the life expectancy of 13 and 14 other countries for females and males, respectively.)[6]

Because many infectious diseases are controlled and Americans are living longer, it is not surprising that chronic health problems, which are often associated with aging (e.g., heart disease, cancer, stroke, and lung disease), are among the leading causes of illness and death. Some conditions are wholly or partly the result of individual choices about smoking, diet, or exercise, but other health problems may also be associated with exposure to environmental pollutants.

The trend data for the diseases presented in this section provide a valuable national overview of the U.S. population. Exhibit 4-3 summarizes the national trends for death rate (number of people dying per year), and incidence rate (number of people developing the disease per year) or prevalence (part of the population affected by a condition or disease). Exhibit 4-4 shows trends in death rates for people age 65 and older.

Exhibit 4-2: Life expectancy and infant mortality in the United States





Note: Infant is defined as under 1 year of age.

Source: Pastor, R.N., et al. *Chartbook on Trends in the Health of Americans. Health, United States, 2002.* 2002.

Cancer

National cancer death rates declined overall during the 1990s,[7] but cancer is still the second-leading cause of death in the U.S., and the number of people who develop cancer each year has actually increased since 1973.[8] Although the overall death rates have dropped for some types—leukemia and breast, cervical, colorectal, stomach, and uterine cancers—the death rates for lung cancer and skin cancer, the most common type of cancer in the country, have increased.[9] The number of people developing cancer shows the same mixed results for different subsets of the U.S. population. For example, lung cancer rates have declined for men but increased for women since 1973, and leukemia rates have declined among adults but not among children.[10]

Cardiovascular Disease

Cardiovascular diseases (CVD) are any that involve the heart and blood vessels. Examples are high blood pressure and hardening of the arteries, which can lead to heart attacks, strokes, and disability. Until age 65, more men than women

Health Data: Disease Mortality Versus Disease Morbidity

Disease mortality (death). *This is an easy and reliable outcome to measure; reporting deaths is a legal requirement supported by a national collection system. A sudden increase in deaths due to identical causes in one geographic region can alert health officials to an environmental problem, such as a waterborne disease outbreak. But in completing death certificates, officials may not always be aware of underlying factors such as environmental exposure or genetic factors as potential causes of birth defects or death.*

Disease morbidity (illness). *Morbidity data—the number of people who have a particular illness—can be useful in linking current health conditions to possible environmental factors, in analyzing disease trends, and/or identifying factors that cause specific diseases or trends. For example, the decline in lung cancer in men has been related to the decline in smoking. But such data are not always available and are frequently reported without causal association. State and federal agencies may ask hospitals and clinics to report admitted cases of asthma, heart attacks, cancer, or other diseases, but such requests lack the force of law in many states. Full reporting in one geographic area may create the false impression of a hot spot for a certain disease, whereas poor or underreporting masks the incidence of disease nationwide.*

Exhibit 4-3: Select disease trends

Disease	National Trend: Death Rate	National Trend: Incidence*
Cancer (overall)	Decreasing (children[1] and adults[2])**	Increasing (children[1] and adults[3])*
Lung Cancer	Increasing[3]	Increasing (F[3]) Decreasing (M[3])
Skin Cancer (Melanoma)	Increasing[3]	Increasing[3]
Blood Cancer (Leukemia)	Decreasing (adults[3])	Increasing (children[1]) Decreasing (adults[3])
Cardiovascular Diseases (CVD) (Heart Disease)	Decreasing[4]	Not reported
Respiratory/Lung Diseases Chronic Obstructive Pulmonary Disease (COPD), including chronic bronchitis and emphysema	Increasing[5]	Not reported
Disease	**National Trend: Death Rate**	**National Trend: Prevalence*** **
Asthma	Increasing[6] (children and adults)	Prevalence Increasing[6] (children) Prevalence Decreasing[7] (adults)

[1] 1975-1998 [2] 1990-1998 [3] 1973-1998 [4] 1950-1998 [5] 1980-1998
[6] 1980-2001 [7] 1997-1999

F=Females; M=Males

*Incidence trend is reported, unless specified otherwise. Incidence is the number of new cases of a disease in a given time period.

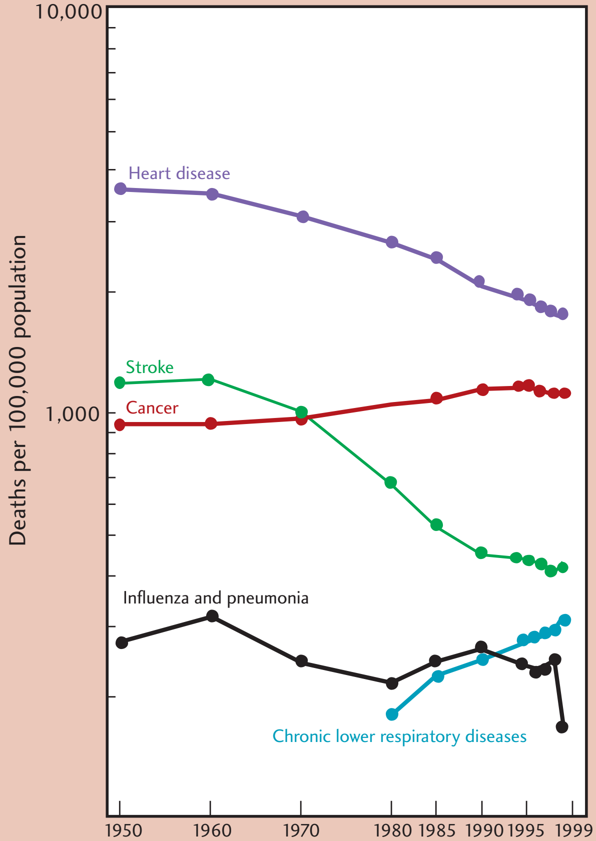
**Rates for specific cancers may vary from these trends.

***Prevalence is the part of the total population affected by a condition or disease.

Note: Environmental pollutants may be only one small contributor to health effect trends.

Sources: NIH, National Cancer Institute, Surveillance, Epidemiology, and End Results (SEER) Program, 1973-1998; CDC, National Center for Health Statistics (NCHS), National Vital Statistics Systems (NVSS), 1950-1998; CDC, NCHS National Health and Interview Surveys, 1980-2001.

Exhibit 4-4: U. S. death rates due to leading causes of death among persons 65 years of age and over, 1950-1999



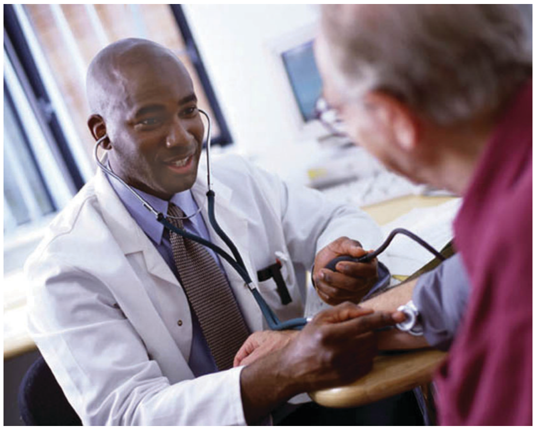
Note: Causes of death shown are the five leading causes of death among persons 65 years of age and over in 1999. Data are plotted on the log scale.

Source: Pastor, R.N., et al. *Chartbook on Trends in the Health of Americans. Health, United States, 2002.* 2002.

have CVD, but after that age, the percentages are the same for women and men. After age 74, a higher percentage of women than men have CVD. The overall mortality trend for CVD has declined dramatically since the 1950s (Exhibit 4-4). Advances in the prevention and treatment of heart disease and stroke rank among the major public health achievements of the 20th century.[11] Heart disease remains the leading cause of death in the U.S., and stroke is third.

Respiratory and Lung Diseases

Chronic obstructive pulmonary disease (COPD) encompasses a group of health conditions such as obstructed airflow and breathing-related symptoms. Chronic bronchitis and emphysema, for example, are classified as COPD. In 1999, COPD was the fourth-leading cause of death in the U.S.[12] Between 1980 and 1998, death rates for COPD increased for all racial and ethnic groups in the nation, reflecting in large part the effects of cigarette smoke.[13,14] Death rates for males began to decline slightly between 1993 and 1998; by contrast, death rates for females have steadily increased since 1980.[15] Mortality data may not give a complete picture of the environmental impact of the disease, because many people with COPD have progressive disability, not immediate death.



Asthma

Asthma is a disorder of the respiratory system characterized by labored breathing, wheezing, cough, and pain or tightness in the chest. It is a common chronic disease in children, and in adults it is more common in females and African Americans. Although the number of adults with asthma has declined slightly since 1997, childhood asthma is on the rise.[16] Asthma death rates for adults have also increased since 1980. The groups that have the highest incidence, women and African Americans, also have the highest death rates.[17] The prevalence of asthma shows regional differences; it is highest in the Northeast and lowest in the South. In addition, in a 1996 survey, people who lived in a central city reported a higher percentage of asthma cases than those who lived elsewhere.[18] Asthma is believed to have a genetic component, but airborne allergens and irritants in the home, workplace, and community can aggravate the disease and trigger attacks.

Gastrointestinal Illnesses

The gastrointestinal tract includes the mouth, esophagus, stomach, small intestine, and the large intestine. Gastrointestinal infections and illnesses are caused by several types of microorganisms (bacteria, viruses, and parasites). The Notifiable Disease Program has recommended seven gastrointestinal illnesses caused by microorganisms for reporting: cholera, cryptosporidiosis, *E. coli* O157: H7, hepatitis A, salmonellosis, shigellosis, and typhoid fever. These seven illnesses are indicators of gastrointestinal illness prevalence. They can cause vomiting, diarrhea, fever, and dehydration, and they are transmitted primarily by water or food contaminated with feces or by personal contact with an infected person or animal. Untreated human sewage and runoff, especially when it contains animal wastes, are sources of contamination. Cholera and typhoid fever rarely occur in the U.S. but are included because they can be severe illnesses and because a sudden increase in reported cases could flag a public health problem. The number of deaths attributed to microorganism-induced gastrointestinal illnesses recently increased in the U.S., after decades of relatively stable death rates.[19] The increases were particularly dramatic in young children (less than 6 years of age) and older Americans (more than 65 years of age). Many cases of gastrointestinal illnesses go unreported or are not diagnosed, making it difficult to estimate the number of people affected every year.[20,21] Often, depending on the severity of symptoms, an infected person may not visit a doctor or hospital, which further contributes to the underestimation of gastrointestinal illness.

What are the trends for children's environmental health issues?

Important environmental health issues for children include infant mortality, low birth weight, childhood cancer, childhood asthma, and birth defects. Since 1950, infant mortality has steadily declined in the United States. Disorders related to premature birth or low birthweight are the second-leading cause of infant death, after birth defects. The number of low birthweight infants born each year increased between 1991 and 2000, with the greatest increase for white infants. [22] Despite that increase, rates of infant mortality and low birth-weight for African American infants are more than twice those for white infants. [23]

Death rates for childhood cancer have declined since 1975, largely because of improved treatment. [24] During the same period, however, the number of children who develop cancer each year has risen. Leukemia, lymphoma, and central nervous system cancers are the most prevalent types of childhood cancer. [25] In 1999, cancers were the second-leading cause of death for children between 5 and 9 years of age and the third-leading cause of death for children between 1 and 4 years of age.[26]

Identified asthma prevalence in children has increased since 1980, especially for children age 4 and younger and for African American children (Exhibit 4-5).[27] In 2001, approximately 6 million—or 9 percent—of U.S. children less than 18 years old had asthma, compared to approximately 3.6 percent of children in 1980.[28] The number of children ever diagnosed with asthma by a health professional—referred to as asthma lifetime diagnosis—has also increased slightly since 1999. However, the number of children having asthma attacks seems to have leveled off since 1997.[29]

Researchers do not understand completely why children develop asthma or why asthma prevalence has increased in the past two decades. The tendency to develop asthma can be inherited, and several factors may trigger acute asthma attacks, such as dander from dogs and cats, house dust mites (microscopic animals living in indoor house dust), cockroach allergens, and pollen.[30,31] Researchers also believe that air pollutants such as environmental tobacco smoke (ETS), particulate matter, and ozone may increase the severity or frequency of asthma attacks in children who have the disease.[32,33,34]

It is important to note that air quality has generally improved during the time that asthma prevalence in children has increased. For example, over the past 20 years, levels of criteria pollutants (including ozone and particulate matter) have decreased. Also, children's exposure to ETS has declined since the 1980s, as evidenced by a national decline in children's blood cotinine levels, an indicator that measures exposure to ETS. While on the surface, this appears to suggest

Why Children May Be Especially Vulnerable to Some Environmental Pollutants

- *Children's nervous, immune, digestive, and other systems are still developing, which may reduce their natural protection and ability to process or inactivate some pollutants.*
- *Children eat more food, drink more fluids, and breathe more air in proportion to their body weight than adults, and they have a more rapid metabolism, which can increase their exposure to some pollutants, but can also reduce exposure to other pollutants.*
- *Children's behaviors, such as crawling and placing their hands and objects in their mouths, may allow more pollutants to enter their bodies.*

Children's Environmental Health: Selected Indicators

Infant mortality

Low birthweight incidence

Childhood cancer mortality

Childhood cancer incidence

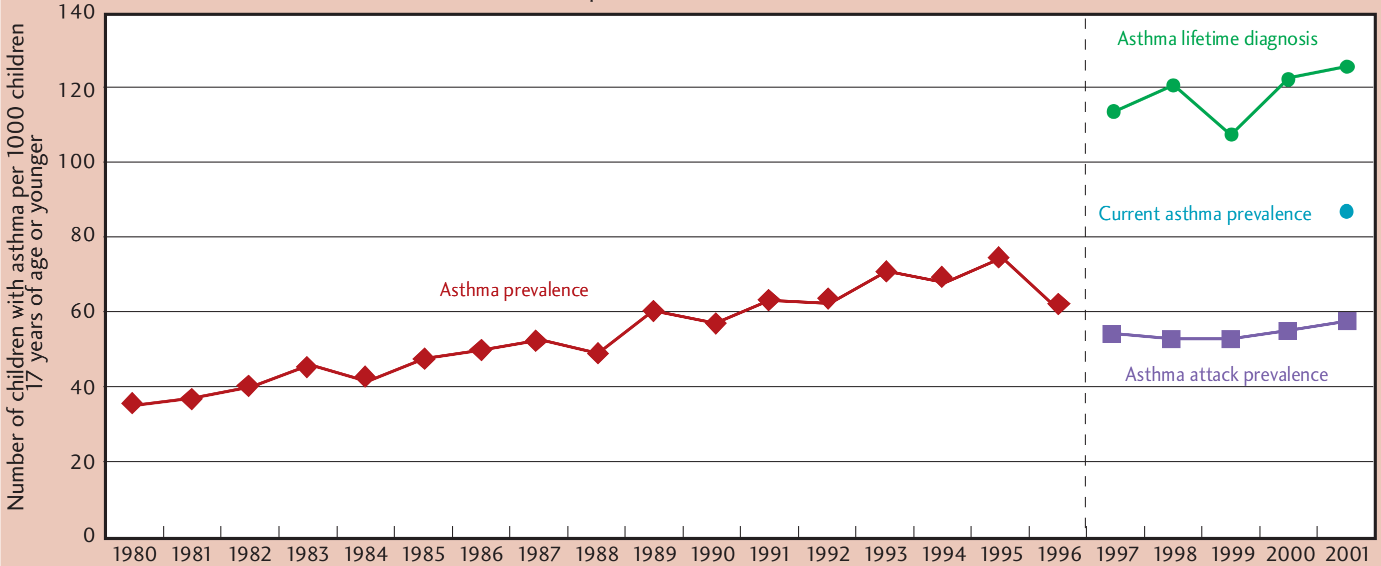
Childhood asthma mortality

Childhood asthma prevalence

Deaths due to birth defects

Birth defect incidence

Exhibit 4-5: Asthma prevalence, 1980-1996, asthma lifetime diagnosis, current asthma, and asthma attack prevalence, 1997-2001, in children



Note: The survey questions for asthma changed in 1997; data before 1997 cannot be directly compared to data in 1997 and later.

Source: Based on and updated from Akinbami, L.J. and K.C. Schoendorf. *Trends in Childhood Asthma: Prevalence, Health Care Utilization and Mortality.* 2002. Data from CDC, National Center for Health Statistics, National Health Interview Surveys, 1980-2001.

that air pollution is not related to the incidence or prevalence of asthma, there are too many complexities and uncertainties to draw this conclusion. For example, although air quality has improved at a national level, areas such as inner cities, where there is a higher prevalence of asthma, continue to experience intermittent exposure to poorer air quality, which may contribute to asthma prevalence. It is also possible that other environmental factors may make children more sensitive to air pollution; increased sensitivity could cause asthma rates to rise even as ambient air quality improves. For example, indoor air pollutants that are not monitored at a national level may trigger asthma attacks (in addition to tobacco smoke, which is monitored, as discussed previously).

Birth defects are the leading cause of infant mortality, accounting for almost 20 percent of all such deaths in 1999.[35] Defects that occur most often are those that affect the heart and lungs. A large number of birth defects may be due to genetic factors. It is unclear at this time what role environmental pollutants have in developing birth defects, but some studies suggest possible environmental links. Because some birth defects are not recognized immediately, they are underreported on birth an death certificates, and the overall problem may be underestimated.[36,37] Also, many serious birth defects are not evident until later in life—an additional factor in underreporting.

Environmental Pollution and Disease

Many studies in people have demonstrated an association between environmental exposure and certain diseases or other health problems. Examples include radon and lung cancer; arsenic and cancer in several organs; lead and nervous system disorders; disease-causing bacteria such as *E. coli* O157: H7 (e.g., in contaminated meat and water) and gastrointestinal illness and death; and particulate matter and aggravation of heart and respiratory diseases.

To understand the relationship between health and the environment, scientists study a series of events that begins with the release of a pollutant into the environment and may end with the development of disease in a person or a population. Exhibit 4-6 broadly illustrates these events: (1) release of pollution into the environment (air, water, food, soil, and dust), (2) exposure through a variety of activities (inhalation, skin contact, and ingestion of contaminated media), and (3) the development of disease or other health problems.

Elucidating the linkage between environmental pollution and disease is challenging. We understand this linkage fairly well for some pollutants, such as those listed above, but poorly for others. This section describes some of the challenges to elucidating those linkages, and uses examples to highlight the role that indicators can play in strengthening our understanding of that linkage and in supporting environmental management efforts.

Environmental Pollution and Disease: Selected Indicators

Blood lead level

Cardiovascular disease mortality

Chronic obstructive pulmonary disease mortality

Cholera prevalence

Typhoid fever prevalence

What is the role of the environment in disease?

Decades of research have provided the scientific foundation for understanding the role of the environment in disease. For many pollutants, scientists know with some certainty that exposure to these pollutants, at sufficiently high concentrations, can cause a variety of health effects. For other pollutants, where scientific evidence is less conclusive, scientists can only establish an "association" between exposure and health problems.

Some effects on health may be short-term and reversible, such as irritated eyes from smog. Other effects, such as emphysema, heart disease, and cancer are chronic or even fatal. Some effects may appear shortly after exposure. Others, such as cancer, may require a long lead time before the disease appears.

In many cases, pollution likely is just one of several factors—including diet, exercise, alcohol consumption, and genetic make-up—that influence whether an exposed person will ever become sick. Although exposure to ETS is associated with lung cancer, whether a person will develop cancer from that exposure depends on the amount, frequency, and length of exposure, exposure to other contaminants, and personal characteristics (genes) and behavior (diet and other lifestyle choices).[38] All these factors can be important in illness and premature death, but they are poorly understood, difficult to quantify, and not routinely tracked or reported. Because of these complexities, it is very difficult to establish causal relationships, and few diseases are known to be exclusively the result of exposure to an environmental pollutant. In many cases, only a small portion of the national incidence of a particular disease is likely to be attributed to a specific environmental factor.

Exhibit 4-6: Pathway from pollution to exposure to potential health effects

Further complicating the picture is the fact that several segments of the population may be at higher risk for damage or disease from environmental pollutants. Potentially sensitive groups include children; older Americans; people with existing health problems such as diabetes, respiratory disease, or heart disease; and persons with compromised immune systems, including those who have HIV/AIDS or are undergoing cancer chemotherapy. Poor or other disadvantaged populations may live in more polluted environments that expose them to higher concentrations of pollutants. Understanding the impacts of pollutants on such sensitive groups is important for those people directly, as well as for the development of protective national health standards and policies.

Children may be more vulnerable to some environmental pollutants than adults for a number of reasons related to their size, growth, and behaviors. Further, children may become ill from exposures that would not affect adults.

Older Americans may also be especially vulnerable to harmful health effects associated with environmental pollutants, in part because some health problems take many years to develop. A long life span may provide the time needed for occupational or cumulative environmental exposures to induce illness or disease. Also, because of medical advances, many older Americans may be living with health conditions that previously shortened life spans. And, older Americans may have preexisting conditions—such as heart ailments, diabetes, or respiratory disease—that reduce their tolerance to pollutants. Even relatively healthy older people may, merely as a result of age, have a diminished capacity to fight infections, pollution, or other causes of stress to their systems that might have posed little risk when they were younger. Harmful substances may be processed and eliminated from the body more slowly in older people, which can prolong exposure to those substances and increase susceptibility to associated health problems. Older people are also more likely to become dehydrated and experience other serious consequences of gastrointestinal disease.

Sorting out the role of all these risk factors—including the environment—and their interactions is a major challenge of scientific research. In addition to the tools already available for elucidating the linkage between environmental exposure and disease, EPA is exploring the use of indicators to complement the traditional tools—exposure assessment, toxicology, and human studies—that are used to evaluate the potential impacts of environmental exposures. Three examples are presented below that illustrate how indicators can play a role in elucidating linkages between environmental pollution and health problems. In two of these examples (lead and waterborne diseases), indicators also play a key role in focusing the environmental protection decision and in evaluating the success of those decisions.

Health Effects of Exposure to Lead

Lead, a naturally occurring metal, has been used to produce gasoline, ceramic products, paints, and solder. In homes built before 1978, lead-based paint and lead-contaminated dust from paint are the primary sources of exposure to lead. Major initiatives have been implemented to reduce lead exposure by phasing lead out of gasoline, paint, solder, and plumbing fixtures.

Health problems from lead exposure are a major environmental health problem because exposure to lead is widespread and can cause health effects at relatively low levels. Substantial data are available to link lead exposure with health effects. Lead adversely affects the nervous system, can lower intelligence, and has been associated with behavioral and attention problems. It also affects the kidney and blood-forming organs.[39] Children and the developing fetus are more vulnerable to the effects of lead than adults.

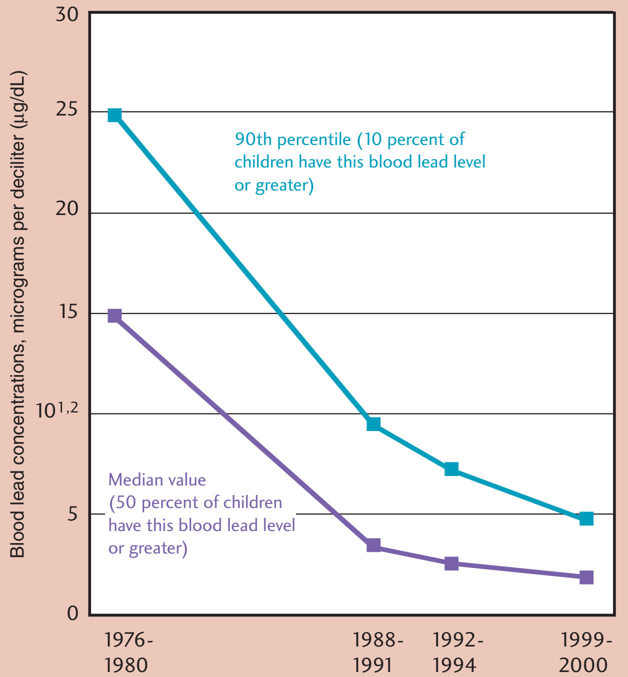
The level of lead in blood has long been used as an indicator of exposure to lead. And, because the linkage between lead exposure and health effects is so strong, blood lead is also used as an indicator of adverse effects on the nervous system.

In the 1970s, lead poisoning occurred increasingly in children who did not live in dwellings with lead-based paint, suggesting that another source or sources of lead exposure were of even greater concern than lead paint. Research found that combustion of leaded gasoline was the primary source of lead in the environment. In the 1970s, EPA promulgated regulations to ban lead in gasoline. Since that time, concentrations of lead in blood samples and in ambient air have declined significantly (Exhibit 4-7). In young children, the median concentration of lead in blood decreased by 85 percent from 1976 to 1999–2000 based on nationwide surveys (Exhibit 4-8).[40]

Exhibit 4-7: Lead used in gasoline production and National Health and Nutrition Examination Survey (NHANES) blood lead averages, 1976-1980

Source: National Research Council. *Measuring Lead Exposures in Infants, Children and Other Sensitive Subpopulations.* 1993.

Exhibit 4-8: Concentration of lead in blood of children age 5 and under, 1976-1980, 1988-1991, 1992-1994, 1999-2000



[1] 10 µg/dL of blood lead has been identified by CDC as elevated, which indicates the need for intervention. (CDC. *Preventing Lead Poisoning in Young Children.* 1991.)

[2] Recent research suggests that blood levels less than 10 µg/dL may still produce subtle, subclinical health effects in children. (Schmidt, C.W. *Poisoning Young Minds.* 1999.)

Source: EPA. *America's Children and the Environment-Measures of Contaminants, Body Burdens, and Illnesses, Second Edition*. February 2003. Data from CDC, National Center for Health Statistics, National Health and Nutrition Examination Survey, 1976-2000.

But national averages of blood levels tell only part of the story. Between 1999 and 2000, approximately 430,000 children ages 1 to 5 (about 2 percent) had elevated blood lead levels (10 µg/dL or greater) from eating paint chips or inhaling lead-containing dust in older homes, primarily in urban areas.[41] Even today, lead poisoning is considered to be a serious environmental hazard in young children in the U.S.[42] Several major metropolitan areas, including Chicago, Detroit, Milwaukee, Palo Alto, and St. Louis, are evaluating blood lead levels of young children, focusing on areas at high risk (i.e., older housing and poorer neighborhoods), to study and address potential problems (see box, "Children's Lead Levels Remain a Concern in Urban Hot Spots"). These blood lead screening programs, however, do not report in a systematic fashion to a central location where the data can be evaluated.

Health Effects of Air Pollution

Several outdoor air pollutants are associated with harmful health effects. These include the six "criteria" pollutants—particulate matter, ground-level ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, and lead—for which EPA has established standards to protect human health, including the health of sensitive populations such as asthmatics, children, and the elderly. The burning of fossil fuels is the principal source of these pollutants. Air pollutants can be transported long distances, so they can potentially have effects distant from their source. (See Chapter 1 – Cleaner Air, for further discussion of the health effects related to air pollutants.)

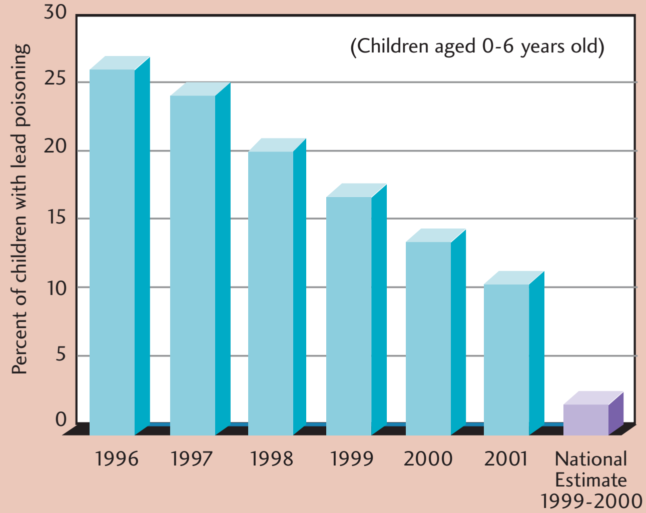
Air pollution has been associated with several health problems, including reported symptoms (nose and throat irritation), acute onset or exacerbation of existing disease (e.g., asthma, hospitalizations due to cardiovascular disease), and premature deaths. The impact of air pollution on health was underscored in December 1952 when a slow-moving area of high pressure came to a halt over the city of London. Fog developed over the city, and particulate and sulfur pollution began accumulating in the stagnating air mass. Smoke and sulfur dioxide concentrations built up over 3 days. Mortality records showed that deaths increased in a pattern very similar to that of the pollution measurements. An estimated 4,000 extra deaths occurred over a 3- to 4-day period. This represents the first quantitative air pollution exposure data with a link to health.

While the London episode highlighted the hazard of extreme air pollution episodes, it was unclear whether health effects were associated with lower concentrations. By the 1970s, the association between respiratory disease and particulate and/or sulfur oxide air pollution had been well established.[43] Improvements in the measurement of air pollution and health endpoints, plus advances in analytical techniques, have made it possible to quantitatively evaluate air pollution and health. For example, research has shown that many air pollutants may contribute to the onset or aggravation of heart disease, especially carbon monoxide and fine particulate matter ($PM_{2.5}$).[44, 45, 46]

Children's Lead Levels Remain a Concern in Urban Hot Spots

Because lead in outdoor air has been reduced to very low levels, the lead dangers to children today are primarily from ingesting and inhaling lead-containing paint dust or eating paint chips in older homes, most of which are in urban areas. Several metropolitan health departments are addressing the problem by using geographic information systems and maps depicting areas of housing with potential lead hazards, as well as areas where children's blood lead levels are high (based on testing of the general population), to identify high-risk areas and promote compliance with lead hazard regulations. In Chicago, for example, EPA Region 5, the U.S. Department of Housing and Urban Development, and the city have taken enforcement action against property managers and landlords who did not disclose potential lead hazards to tenants. The city is also providing outreach and education materials to these high-risk areas. The percentage of Chicago children with elevated blood lead levels above 10 µg/dL has declined substantially since 1996, although many still have blood lead levels above the national average (Exhibit 4-9).

Exhibit 4-9: Percent of screened children in Chicago having elevated blood lead levels greater than 10 micrograms per deciliter (> 10 µg/dL), 1996–2001



Note: 10 µg/dL of blood lead has been identified by CDC as elevated, which indicates the need for intervention. (CDC. *Preventing Lead Poisoning in Young Children.* 1991.)

Source: Graphic developed for this report by Chicago Department of Public Health, Childhood Lead Poisoning Prevention Program. For 1996-2001, source is annual Illinois Department of Public Health, Childhood Lead Poisoning Surveillance Reports. For 1999-2000, source is CDC. *Second National Report on Human Exposure to Environmental Chemicals.* 2003. Data from CDC, National Health and Nutrition Examination Survey (NHANES).

Particulate Matter

Particulate air pollution is associated with increased daily mortality in many U.S. communities and other countries. The elderly and those with preexisting diseases are particularly vulnerable.[47] Exposure to ambient particulate matter has also been associated with an increased number of hospital admissions and visits to doctors due to cardiovascular problems and respiratory disease.[48] Some studies show that exposure to particulate matter exacerbates asthma. Long-term exposure to particulate matter has been associated with increased deaths from heart and lung diseases, increased respiratory disease and bronchitis and with decreased lung function in children.[49]

Ozone

Repeated short-term exposures to ozone may damage children's developing lungs, which may lead to permanent reductions in lung function.[50] Controlled studies in healthy adults have demonstrated ozone-induced lung inflammation, decrements in lung function, and associated respiratory symptoms, such as cough and pain on deep inspiration.[51] Ozone exposures have also been associated with an increased number of hospital admissions and visits to doctors.[52]

Indicators

As noted in Chapter 1 – Cleaner Air, national average criteria pollutant levels, including particulate matter and ozone levels, have decreased over the past 20 years. As discussed earlier, however, there are limitations in using these national air pollution data to evaluate rates of asthma attacks occurring during acute exposure episodes. Possible future health indicators for air pollution include death due to respiratory and cardiovascular disease, increased hospital admissions for respiratory and cardiovascular disease, and subtle changes in the cardiovascular system that can increase people's risk of heart attacks and other cardiovascular effects. Use of these indicators is still challenged by limits in our understanding of how much air pollution contributes to the risk of cardiovascular and respiratory disease.

Waterborne Diseases

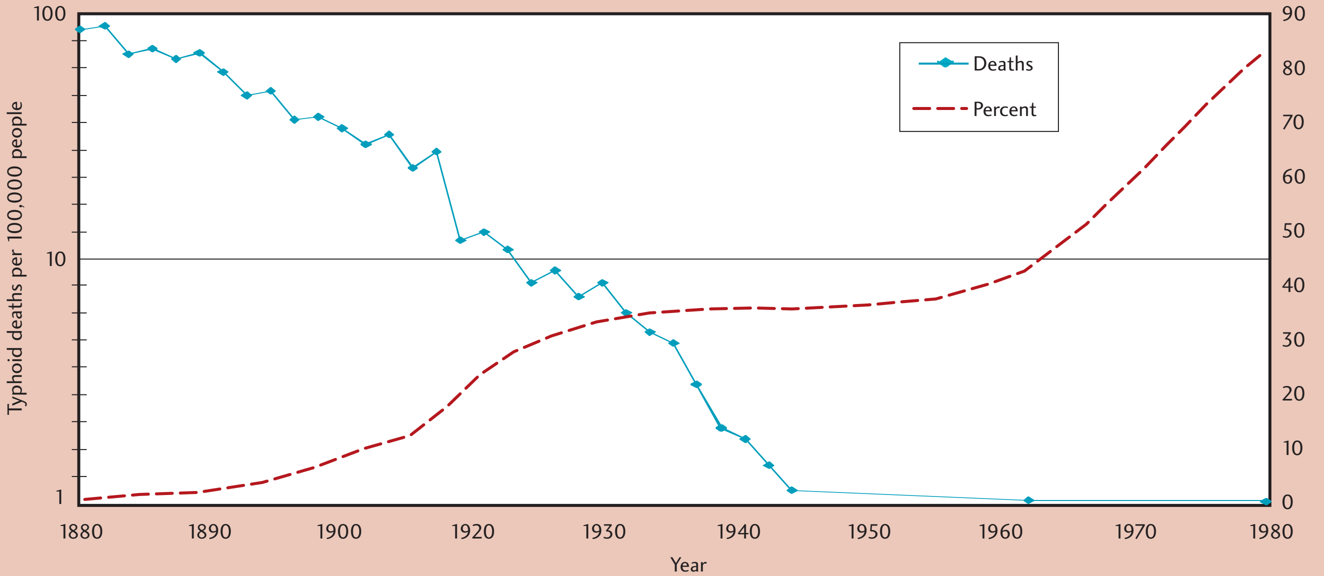
In the early 20th century, waterborne diseases such as cholera and typhoid fever were major health threats across the U.S. Deaths due to diarrhea-like illnesses, including typhoid, cholera, and dysentery, were the third largest cause of death in the nation. For instance, more than 150 in every 100,000 people died from typhoid fever each year.

Around that time, scientists began to understand the cause of these diseases. They had identified the bacteria responsible for most diarrheal deaths (typhoid, cholera, and dysentery) and elucidated how these bacteria were transmitted to and among humans. Infected and diseased individuals shed large quantities of microbes in their feces, which flowed into and contaminated major water supplies. This contaminated water was then distributed untreated to communities, which used the water for drinking and other purposes. This created a continuous transmission cycle.

Once treatment (filtration and chlorination) of drinking water was initiated to remove pathogens, the number of deaths due to diarrheal diseases dropped dramatically in communities with treated water. Deaths due to typhoid fever were tracked throughout the early 20th century, as drinking water treatment was implemented across the country, providing an indicator of the success of this environmental management strategy (Exhibit 4-10).

Drinking water treatment is one of the great public health success stories of the 20th century. Not only did it dramatically and significantly reduce death rates from waterborne disease, it also increased life expectancy and reduced infant mor-

Exhibit 4-10: Percent of population with treated water versus typhoid deaths in the United States, 1880-1980

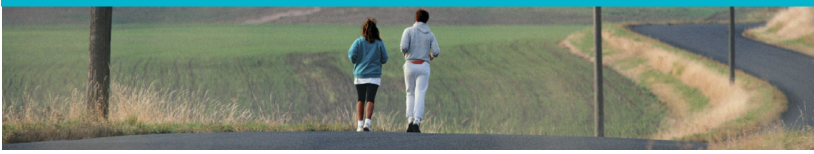


Source: Craun, C.G. *Waterborne Diseases in the United States*. 1986; Whipple, G.C. *Typhoid Fever - Its Causation. Transmission and Prevention.* 1908; Fox, K. National Risk Management Research Laboratory, personal communication, 2003.

tality. Today, public health is protected against new and emerging waterborne microbial contaminants by continual improvements to the drinking water treatment process.

This example illustrates how a link was made between gastrointestinal disease (an outcome indicator) and exposure to pathogens in drinking water. Based on this connection, officials were able to take effective action to protect public health. They also were able to use an outcome measure (deaths due to typhoid) to monitor the success of these protective actions.

Today, deaths due to typhoid, cholera, and dysentery are so rare in the U.S. that they cannot serve as indicators to evaluate drinking water management decisions. The actual number of cases of typhoid, cholera, and dysentery are tracked to some extent; however, the reporting of these cases is not federally required. The waterborne disease outbreak surveillance system is a passive system in that it relies on state health departments to voluntarily report their outbreaks to CDC. (For further information on waterborne diseases, see Chapter 2 – Purer Water.)



Measuring Exposure to Environmental Pollution

How can exposure data advance understanding of the role of the environment in disease?

"Exposure" refers to direct human contact with a pollutant (e.g., through breathing contaminated air, drinking contaminated water, or eating contaminated food). Measurements of such exposures can help identify which pollutants may cause health problems and at what levels. They can also provide the basis for determining appropriate actions to limit exposure and associated harmful health effects. For example, these data can enable health officials to respond to a health threat in a specific community (e.g., issue code red alerts when air pollution is a concern). This section describes the three key approaches—environmental monitoring, personal monitoring, and biomonitoring—that scientists use to measure how much pollution we are exposed to and how exposure data contribute to understanding the role of the environment in disease. No approach is best suited to all pollutants. Different approaches are appropriate to different types of pollutants, and each approach has strengths and weaknesses.

Environmental Monitoring

Historically, human exposure has often been estimated through environmental measurements of ambient pollutant concentrations (e.g., particulate matter in air, bacteria in water or food). However, the presence of a pollutant in the environment does not necessarily mean that anyone is exposed. For example, people must actually breathe contaminated air or ingest bacteria-laden food and water for exposure to occur.

Monitoring ambient pollutant levels is critical to measuring exposure for several pollutants, including air pollution (e.g., particulate matter, ozone, nitrogen oxides, and sulfur dioxide), radiation, biological pollutants (e.g., molds, pollen, infectious agents), and disinfection by-products, which are formed when chlorine is used to treat drinking water. For instance, measurements of concentrations of pollutants in outdoor or indoor air can be coupled with human activity patterns (e.g., time spent working, exercising outdoors, sleeping) to estimate human exposures. This approach was used to establish national air and water quality standards for many pollutants that protect the U.S. population from harmful health effects.

Personal Monitoring

With personal monitoring, the monitoring device is worn by individuals as they proceed through their normal activities. This approach is most common in workplaces. The radioactivity sensors worn by nuclear power plant workers are one example. Personal monitoring has been used to estimate total human exposures, including exposures from the air people breathe, the water they drink, and the food they eat.[53] One advantage of personal monitoring is that the data provide valuable insights into the sources of the pollutants to which people are actually exposed. A challenge with personal monitoring is ensuring that sufficient sampling is done to be representative of the population being studied.

Biomonitoring

Several environmental pollutants, notably heavy metals and some pesticides, can accumulate in the body over time, often with increasing risk of harm. These pollutants or their breakdown products (i.e., metabolites formed when a pollutant is broken down in the body) leave residues in the body that can be measured, usually in the blood or urine. These residues reflect the amount of the pollutant in the environment that actu-

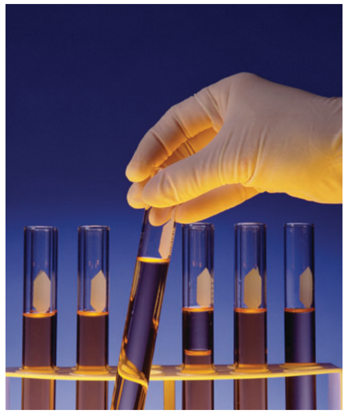
Measuring Exposure to Environmental Pollution: Selected Indicators

Blood lead level

Blood mercury level

Blood cotinine level

Urine organosphosphate level to indicate pesticides ally gets into the body. The approach of measuring pollutant levels in tissue or fluid samples from individual people is called "biomonitoring."



National-scale biomonitoring data can be useful as indicators of the distribution of exposure across the entire population to a variety of pollutants. Also, such data provide an important bridge to understanding the relationships between ambient pollutant concentrations (e.g., in air, water), exposures to these pollutants, and health problems. Biomonitoring data provide exposure information that may help alert physicians, scientists, and health officials to diseases that result from exposure to environmental chemicals. The data are also useful for establishing reference ranges that can be used to identify people with unusually high exposure or the percentage of the population that has pollutant exposures above levels considered to be elevated (e.g., lead).[54]

Health and environmental agencies are using biomonitoring measures and trend data to improve understanding of the relationship between exposure to environmental pollutants and health. For example, CDC is using biomonitoring data to assess environmental pollutant exposures in the U.S. population. In 2001, CDC provided data on 27 pollutants present in the blood and urine of a small sample of the U.S. population.[55] In January 2003, CDC released data on blood and urine residues for 116 environmental chemicals in a much larger, nationally representative population sample.[56]

Biomonitoring data are already available for metals (e.g., lead, mercury, cadmium), cotinine (a measure of environmental tobacco smoke [ETS]), volatile organic chemicals, organophosphate pesticides, organochlorine pesticides, phthalates, polychlorinated biphenyls (PCBs), dioxin and dioxin-like compounds, and polycyclic aromatic hydrocarbons (PAHs). Future biomonitoring will build the trend data showing whether levels of other pollutants are increasing or decreasing in the population.

Although biomonitoring data are highly useful, they have several limitations as an indicator of exposure. These data do not provide information about how the exposure occurred or the source(s) of exposure, and in some cases, they do not distinguish among different pollutants that may leave identical residues in the body. For example, biomonitoring can determine that a person has been exposed to carbon monoxide, but not whether the source is ETS, a faulty gas stove, or vehicle emissions on a highway. These limitations may make it difficult to identify actions that would reduce or prevent such exposures or to correlate them to disease. Nonetheless, for some pollutants national biomonitoring data are useful indicators of exposure on a national scale.

The following three examples—the heavy metals lead and mercury, ETS, and organophosphate pesticides—highlight the findings of the ongoing CDC biomonitoring efforts and how these findings can advance efforts to protect human health.

Heavy Metals

Gathering information on heavy metals in the U.S. population is important because those metals are highly toxic at sufficiently high doses, and even low-level residues of certain metals may be of concern. Concentrations of lead in blood—a demonstrated indicator of harmful effects on the nervous system—have declined significantly, especially since the 1970s, when lead was banned from gasoline.

Environmental exposure to mercury, another heavy metal, is of particular concern. Mercury can be transformed into methylmercury by bacteria in soil and sediments and then can move up the food chain, accumulating in fish, which are a major source of exposure for people. Methylmercury has been associated with harmful effects on the nervous system, especially in a developing fetus. When a pregnant woman eats methylmercury-contaminated fish, the child she is carrying may later experience harmful effects, including learning and developmental problems.[57] The same is true for young children exposed to methylmercury directly. Indigenous and tribal populations and others who rely heavily on fish as a major food source may also suffer nervous system effects.

In 1999 and 2000, total mercury blood levels (both inorganic and organic forms) were evaluated in a nationally representative survey of approximately 700 young children (ages 1 to 5 years) and 1,700 women of childbearing age (16 to 49 years). The results show that the mercury levels in women of child-bearing age were less than 58 ppb—a level associated with a doubling of risk of abnormal performance on neurodevelopmental tests in children exposed in utero.[58,59] Adverse health effects may also occur at levels below 58 ppb. To account for many uncertainties, EPA has determined that children born to women with blood levels of mercury above 5.8 ppb are at some increased risk of adverse health effects. Based on the 1999–2000 survey, about 8 percent of women of child-bearing age had at least 5.8 ppb of mercury in their blood.[60,61] Health officials have been working to promote education and awareness of the hazards of methylmercury-contaminated fish. (See "Consumption of Fish and Shellfish" in Chapter 2 – Purer Water.)

Environmental Tobacco Smoke

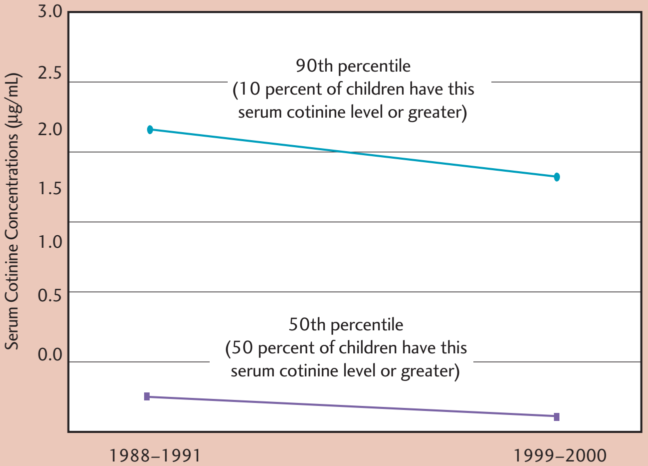
Environment tobacco smoke (ETS) is of special concern in indoor air, where it can concentrate and persist. Cotinine, a breakdown product of nicotine that can be quantified in blood, hair, urine, and saliva, can be used as a measure of exposure to tobacco smoke from both active and passive means. Overall, children's median (50th percentile) blood levels of cotinine have declined 56 percent between the periods 1988–1991 and 1999–2000 (Exhibit 4-11).[62] Between the periods 1991–1994 and 1999–2000, cotinine levels in urine decreased 58 percent for children ages 3 to 11, 55 percent for adolescents ages 12 to 19, and by 75 percent in non-smoking adults, according to a national survey of almost 6,000 people.[63] The declines in children's cotinine levels are in part attributable to the declining number of adult smokers. However, non-smoking children between the ages of 3 and 19 have cotinine levels more than twice those of adults.[64] In 1999–2000, African Americans (all age groups combined) had cotinine levels more than twice those of whites.[65]

ETS is a known cancer-causing agent in people, and long-term exposure to ETS is associated with an increased risk for lung cancer and other diseases.[66] Children are at particular risk from ETS, which may exacerbate asthma in children who have the disease and greatly increase the risk for lower respiratory-tract illness, such as bronchitis and pneumonia, among young children.[67]

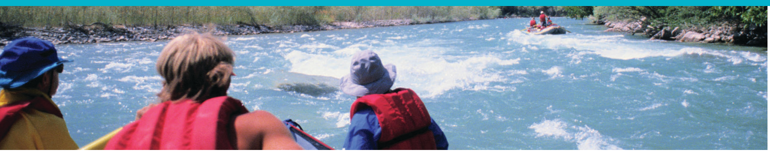
Organophosphate Pesticides

Organophosphate pesticides account for about half of the insecticides used in the U.S. Exposure to these pesticides occurs primarily from ingestion of food products or from home and garden uses, like lawn and crack and crevice treatments, although many household uses are being phased out or have stopped altogether in recent years. In a 1999–2000 nationwide survey, common breakdown products of several organophosphate pesticides were found in the urine of approximately 50 percent of the nearly 2,000 people sampled, demonstrating fairly widespread public exposure to these pesticides.[68] This study also showed that these pesticide residues were consistently higher in children than in adults.[69] Like lead and mercury, these pesticides can harm the nervous system, but it is not yet known what minimum level causes these effects. Future research will build the trend data showing whether levels of these pesticides are increasing or decreasing in the population and, as noted, CDC has an effort under way to collect those data.

Exhibit 4-11: Concentrations of cotinine in children's blood, 1988-1991 and 1999-2000



Source: EPA. *America's Children and the Environment-Measures of Contaminants, Body Burdens, and Illnesses, Second Edition.* February 2003. Data from CDC, National Center for Health Statistics, National Health and Nutrition Examination Surveys, 1988-1991 and 1999-2000.



Challenges in Developing Human Health Indicators

Human health indicators provide important tools that regulatory agencies can use to identify environmental health problems, develop programs to reduce the problems, then gauge the success of those efforts. For example, the declining levels of lead in children's blood confirm that the nation's strategies to remove lead from gasoline, water, and paint have successfully reduced exposure to lead. Similarly, the decline in urinary cotinine levels confirms that efforts to reduce smoking have been successful in reducing exposures to ETS.

For many other pollutants, major knowledge gaps and challenges remain in linking environmental pollution to health problems. Sorting out the role of the environment, the role of other factors (e.g., genetic make-up, lifestyle choices such as diet and exercise), and the importance of their interactions remains an enormous scientific challenge. The time between exposure and the development or diagnosis of disease, as well as the problems of tracking a mobile population, further complicate the issue of clarifying connections between exposure and harm to health. An emerging area of science involves examining the possible combined (additive), synergistic, and cumulative effects of numerous pollutants in the environment. This field of study merits greater development. Finally, not all chemical exposures result in harm to health. With a better understanding of the contribution of environmental factors to the development of disease, EPA will be able to use established health outcome measures—disease trend and exposure data—to enhance environmental management efforts and to assess the effectiveness of those efforts.

Disease registries could be improved to provide valuable assistance in tracking many diseases. Currently, most disease indicators are based on mortality data, which have serious limitations for linking environmental exposures to disease. Data on the number of new cases (incidence) of a disease or the existing cases (prevalence) of a disease in a population can provide better information, but no comprehensive nationwide systems exist for collecting these data. For example, there is currently no national registry for birth defects. Also, it is nearly impossible to get an accurate national picture of the number of people affected by outbreaks of waterborne diseases. Occurrence of endemic waterborne disease is grossly underreported. Submission of waterborne disease information to CDC is strictly voluntary, and state-level data pose problems because the list of gastrointestinal diseases that must be reported varies by state. Also, for an outbreak to be detected, many people need to become ill at the same time, and many cases go unreported or are not diagnosed.

Better national-level disease data that could be linked directly with environmental monitoring data would support efforts to establish connections between disease and environmental exposures. For meaningful comparisons, all data sets should have similar timeframes (the same months or number of years) and locations. Also, national-level efforts would benefit from more data that can be sorted by several relevant factors, such as race (which can help in identifying disparities in health status and outcomes), income, occupation, and residence. Such data can be gathered only through better collaboration between and among environmental and health agencies at all levels, as well as hospitals, clinics, and medical offices. As EPA works to develop environmental indicators that reliably signal trends in exposures and disease, the Agency will also work to improve cooperation with the federal and state agencies that collect relevant information.

Appropriate indicators that address these challenges can help the agencies responsible for monitoring and managing the nation's health to flag and respond to potential problems, such as an upsurge in cases of an environmentally related disease or rising contaminant levels in human tissues. The same indicators might, ideally, show whether pollution control actions are actually reducing the number of people who develop diseases associated with environmental agents. This information will help EPA and other agencies to enhance priority-setting to best protect the health of the nation's people.

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[66] U.S. Environmental Protection Agency. *Air Quality Criteria for Particulate Matter,* Third External Review Draft, 2002. op. cit.

[67] Centers for Disease Control and Prevention. H*uman Exposure to Exposure to Environmental Chemicals,* 2001. op. cit.

[68] Centers for Disease Control and Prevention. *Second National Report on Human Exposure to Environmental Chemicals,* 2003. op. cit.

[69] Ibid.